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Section 3

Sedimentation

Chapter 6

Sediment Sources, Yields, and Delivery Ratios

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Chapter 6
Sediment Sources, Yields, and Delivery Ratios

Introduction

General

Sediment yield depends on the erosion processes at the sediment source and on the efficiency of the system, that transports the sediment to the point of measurement. The sediment yield usually differs at different locations in a stream system.

Many interrelated factors affect sediment yield. Knowledge of each of these factors is important in:

1. Evaluating downstream sediment damages.
2. Determining the location and extent of sediment sources so that effective controls can be planned and installed.
3. Recognizing the relative contribution of the various sources to present and future sediment yield.
4. Determining the sediment storage requirement for designing proposed structural works of improvement.

This chapter presents several procedures for determining sediment sources, sediment yields, and delivery ratios.

Interrelationship of Processes

Sediment yield depends on gross erosion in the watershed and on the transport of eroded material out of the watershed. Only part of the material eroded from uplant areas in a watershed is carried out of the watershed. Variation in the proportion of the eroded material deposited as colluvium at the base of slopes and in swales, as alluvium on flood plains and in channels, and as lacustrine deposits in natural or artificial lakes usually results in variation in the yield rate for different parts of a watershed.

Field determination of sediment yield may require long-term sampling and measuring procedures. A short-term procedure is to extrapolate (and adjust as appropriate) known sediment yield from measured similar watershed in the same physiographic section.

General

Sources of sediment must be delineated to plan an adequate program for reducing downstream sediment yield. Sediment sources include agricultural land, range and forest land, road banks and ditches, stream channels and banks, flood plains, spoil banks, and gullies. In planning a program to reduce sediment yield, the relative importance of the various sources and the methods for treating them must be determined before the physical and economic feasibility of the program can be determined. Sediment derived from sheet erosion can usually be reduced by land treatment measures, whereas that derived from channel-type erosion usually requires structural works.

A sediment source study is made to determine: (1) the origin of the sediment; (2) the rate of erosion from each source; (3) the proportion of the sediment derived from each source; (4) for program planning or structure design, the kinds of treatment that should be recommended for reducing sediment yield; and (5) the relative effect that reducing erosion from the various sources will have on reducing sediment yield and damage.

The relative importance of the sediment source may differ at different locations in a watershed. Therefore, the treatment measures may also vary, depending on the location in the watershed where a reduction in sediment yield is desired.

Determining the Relative Importance of Various Sources

The following items must be considered in the early stages of any study made to determine the location, extent, and relative importance of the sediment sources.

Maps and Aerial Photographs

Careful review of aerial photographs often reveals where erosion is severe and which channels appear to be carrying the heaviest load of sediment. If soil surveys are available, the information on soils, slopes, land use, and erosion conditions recorded on the maps is very helpful. Using all such information as fully as possible saves considerable time in locating the most obvious sources of sediment.

Distinctive Minerals

The presence of distinctive minerals in modern sediment deposits helps in identifying and evaluating sediment sources. Because a watershed may contain contrasting rock formations, the distinctive erosion products of these rock formations may clearly indicate the location of the sediment sources. These distinctive minerals are quartz, micas, iron oxide, feldspar, chert, and calcite; some can be easily identified and traced to their original source. Other watersheds may lack geologic variety and hence may not provide such specific clues to the location of significant erosion.

Colluviation

Another aid in evaluating the sediment sources is the extent and location of colluvial deposition. If a coarse-grained material such as sand or gravel is being actively eroded, it may produce large volumes of sediment, little of which moves very far from the site of erosion. Substantial deposits may form at the foot of the first slope. Fans and valley deposits may form in small tributary valleys or in the next lower valleys downstream.

Procedure

Any procedure requires study of the various types of erosion apparently producing sediment. Sorting the types of erosion according to the treatments that could be recommended to reduce erosion and thus sediment yield will make the effectiveness of the various treatments much easier to evaluate.

Several procedures can be used to determine the relative importance of the various sediment sources. A recommended procedure is to gather information on that part of the sediment yield which can be attributed to each of the various sources. Erosion and the sediment delivery ratio should be estimated above each reach or other point of interest for the drainage area.

The sediment yield at the point of interest must be allocated to the recognized sources. Analyzing the available data, studying the watershed, and considering the sediment delivery ratios and erosion estimates enable the preparation of a table, such as table 6–1, that indicates the relative importance of the sediment sources.

Table 6-1. — Sediment yield from various sources

	Sediment yield from indicated source					
Reach	Sheet erosion	Gullies	Road-banks	Stream-banks	Scour	Total
	Pct.					
1	88	5	2	3	2	100
2	64	28	3	4	1	100
3	36	64				100

General

Sediment yield is the gross (total) erosion minus the sediment deposited en route to the point of concern. Gross erosion is the sum of all the water erosion occurring in the drainage area. It includes sheet and rill erosion plus channel-type erosion (gullies, valley trenches, streambank erosion, etc.). Measurements or estimates of the sediment yield are needed to evaluate sediment damage and its reduction and to determine the sediment storage requirements for proposed structures. The yield of a given area varies with changes over time in precipitation, cover, and land use patterns. For projection into the future, the present sediment yield must be adjusted to allow for expected changes in these factors.

Climatic Factors

The effect of climatic factors such as precipitation, temperature, and wind on sediment yields varies in different parts of the country. Rainfall and runoff are the primary erosion factors throughout the country. Wind erosion is serious in some sections but is not as widespread as water erosion. The erosive power of rainfall depends on its intensity, duration, and frequency. Seasonal distribution of rainfall is of prime importance in cropland areas because of the condition of the cover at the time of erosion-producing rainfall. Prolonged low-intensity rainfalls are less erosive than brief intense storms. Guidance in computing long-term sheet erosion rates is given in Chapter 3.

Watershed Factors

Important watershed factors affecting sediment yield are size of drainage area, topography, channel density, soils, and cover conditions.

Size

In a given physiographic area, the larger the drainage area, the larger the sediment yield, but generally the sediment yield per unit of area (sediment yield rate) decreases as the size of drainage area increases. In mountainous areas, however, the size of the drainage area often makes no difference in the sediment yield rate. Where active channel-type erosion increases downstream as from bank cutting on the mainstream channel, the sediment yield rate may increase as the size of the drainage area increases. The relationship between size of drainage area and the sediment yield rate must therefore be considered carefully.

In a small watershed, sediment is carried shorter distances and areas of high and low sediment production are less likely to counterbalance each other than in a large watershed. There are fewer types of land use or other watershed variables in a small watershed than in a large watershed. In a small watershed the yield rate is higher and varies more than in a large watershed.

In a small watershed in which the land is used according to its capability, both the erosion rate and the sediment yield rate are low. Conversely, a high erosion rate is sharply reflected in a high sediment-yield rate. Larger watersheds tend to have lower average slopes and less efficient sediment transport than smaller watersheds. Size of the drainage area is therefore an important factor in both the total sediment yield and the sediment yield rate.

The relationship between size of drainage area and sediment yield is complicated by many other factors, such as rainfall, plant cover, texture of the sediment, and land use. All these factors must therefore be evaluated in estimating the volume of sediment from an erosion source, the rate of deposition in a proposed reservoir, or the rate of sediment contribution to any downstream location.

Several investigators have illustrated the relationship of watershed size and sediment yield rate with graphs, curves, and charts. Among them are Gottschalk (1948); Brown (1950); Barnes and Maner (1953); Renfro[1]; Roehl[2]; Beer, Farnham, and Heinemann (1966); and Johnson et al. (1974).

Topography

Shape of the land surface is an inherent feature of the physiographic area in which a watershed is located. Many of the problems of soil and water conservation result from the topography of an individual watershed, especially the proportions of uplands, valley slopes, flood plains, or features such as escarpments, canyons, or alluvial fans. Slope is a major factor affecting the rate of onsite erosion, and topography is important in the delivery of upland erosion products to the stream system.

Drainage density, amount of sloping land, and erosion rate are closely related to the stage of erosional development. Youthful areas are characterized by a relatively high proportion of high, nearly flat upland between stream valleys. Youthful watersheds at high elevations may have deep canyons along the principal streams; youthful watersheds consisting of low glacial plains or other flat areas commonly have poorly developed stream courses and relatively low slopes. Watersheds in areas of old topography also have a relatively small amount of sloping land, but most of the uplands are eroded to low elevations and the greatest proportion of land consists of old, broad valley flats. The proportion of sloping land is usually highest in mature areas, where drainage is well developed and either uplands or valley flats are limited. The average gradient and the average sediment yield tend to be higher in mature areas.

Channel Density

The efficiency of a stream system in transporting sediment out of a watershed is affected by the degree of channelization. A watershed with a high channel density (total length of channel per unit area) has the most thorough water runoff and the most rapid and complete transport sediment from the area. Channel density can be measured on aerial photographs with the aid of a stereoscope.

Soil and Cover Conditions

The kinds of soil and cover are important in sediment yield. In general, the more erodible the soil and the sparser the vegetation, the higher the sediment yield. Estimating the average annual sediment yield from a watershed having many kinds of soil and mixed cover is complex and requires a procedure such as use of a soil-loss equation to determine erosion for the various soil-slope-cover combinations in the watershed. Sediment yield tends to be similar in watersheds of similar size, topography, and cover.

Land Use

According to the 1977 SCS National Erosion Inventory, about 28 percent of the 1,500 million acres of non-Federal land in the United States is cropland; 36 percent is grassland, pasture, and

[1] *Renfro, Graham W. Unpublished reports (1952-54) on upper Arkansas, Red River, and other watersheds. USDA, Soil Conservation Service, Ft. Worth, Tex.*

[2] *Roehl, John W. Unpublished study (1957). USDA, Soil Conservation Service, Spartanburg, S.C.*

range; 25 percent is forest; 6 percent is in residential, industrial, transportation, and other urban and built-up areas; and 5 percent is in other uses.

Land use is determined to some extent by the kind of soil. In turn, land use largely determines the type of cover. If a watershed is primarily agricultural and the annual precipitation is more than 20 in., most of the sediment yield usually is from sheet erosion. In most forest and range country and in areas with less than 20 in. of annual precipitation, channel-type erosion usually produces most of the sediment (Brown 1960).

According to the U.S. Department of Agriculture, conversion of forest land to continuous cultivation of row crops increases erosion 100- to 10,000-fold. Plowing grassland for continuous cultivation of row crops increases erosion 20- to 100-fold (Brown 1960). In the United States, cultivated farm fields that annually lose more than 200 tons/acre from water erosion are not uncommon (Gottschalk and Jones 1955, Gottschalk 1965). Small, intensively cultivated watersheds in western Iowa have had annual soil losses as high as 127,000 tons/mi^2 (Gottschalk and Brune 1950).

Because it encompasses such a broad area, agricultural land produces the most sediment, but progress is being made in conserving agricultural soils. Special uses create serious local problems. Examples follow.

Urbanization. — Construction of an industrial park near Baltimore produced at least five times more sediment than was present in the waters immediately upstream (Wolman 1964).

Areas under construction above Lake Barcroft, Va., and Greenbelt Lake, Md., yielded annual peak sediment-yield rates of 25,000 and 5,600 tons/mi^2, respectively (Dawdy 1967).

Strip Mining. — In Kentucky a watershed with 10 percent of its area disturbed by active strip-mining produced 57 times the sediment measured from a similar but undisturbed adjoining watershed (Collier et al. 1964).

Highway Construction. — Sediment yield from an area in Fairfax County, Va., where a highway was being built was 10 times greater than that from cultivated land, 200 times greater than that from grassed areas, and 2,000 times greater than that from forested areas (Vice, Guy, and Ferguson 1969).

Methods of Determination

Depending on the environment and the data available, the average annual sediment yield in a watershed can be determined from: (1) gross erosion and the sediment delivery ratio, (2) measured sediment accumulation, (3) sediment load records, and (4) predictive equations.

Gross Erosion and the Sediment Delivery Ratio

SCS has used this method extensively for many years with success, particularly in humid sections of the country. It is well suited to estimating current sediment yield and predicting the effect of land treatment and land use changes on future sediment yield. The following equation is used to estimate sediment yield:

$$Y = E(DR)$$

where

Y = annual sediment yield (tons/unit area).
E = annual gross erosion (tons/unit area).
DR = sediment delivery ratio (less than 1).

The gross (total) erosion in a drainage area is the sum of all the water erosion taking place. The method of determining the amount of each type of erosion is outlined in Chapter 3 and in other guides. The sediment delivery ratio is estimated from relationships discussed later in this chapter. Sediment yield is the product of gross erosion and the sediment delivery ratio.

Measured Sediment Accumulation

The measured sediment accumulation in reservoirs of known age and history is an excellent source of data for establishing sediment yield, but deposition in reservoirs and sediment yield are not synonymous. For sediment yield, the amount of accumulated sediment must be divided by the trap efficiency of the reservoir. The amount of sediment that has passed through the reservoir plus the amount deposited in the reservoir equals the sediment yield.

The sediment yield of a watershed can be estimated from measured sediment yield from another watershed in the same major land resource area if the topography, soils, and land use of the two watersheds are similar. For direct extrapolation of sediment yield data, the size of the drainage area of the surveyed reservoir should be no less than one-half nor more than twice that of the watershed under consideration. Beyond these limits the annual sediment yield can be adjusted on the basis of the ratio of the drainage areas to the 0.8 power:

$$Y_e = Y_m \left(\frac{A_e}{A_m}\right)^{0.8}$$

where

- Y_e = sediment yield of unmeasured watershed in tons per year.
- Y_m = sediment yield of measured watershed in tons per year (measured annual sediment deposition divided by trap efficiency of surveyed reservoir).
- A_e = drainage area of unmeasured watershed.
- A_m = drainage area of measured watershed.

This relationship must be used with judgment and be confined generally to the humid areas east of the Rocky Mountains.

The amount of sediment accumulated on fans and flood plains over a known period of time can sometimes be used to estimate sediment yield but generally only to verify yield determined by other methods. The procedures for measuring sediment in reservoirs or in valley deposits are discussed in Chapter 7.

Suspended-Load Records

Suspended sediment can be measured by sampling, and water discharge can be determined by gaging at stream cross sections. Sediment yield can be estimated from these data. Sediment concentration in milligrams per liter or parts per million is converted to tons per day by multiplying the average concentration by the volume of water discharged on the day of record and a conversion factor (usually 0.0027). Tons of sediment per day plotted against water discharge in cubic feet per second is a sediment rating curve. The data plotted on log-log paper often approximate a straight line through at least a major part of the range of discharge (see fig. 6–1).

If discharge and concentration data are available, the average annual sediment yield can be estimated by using a flow-duration curve or equivalent tabulations (Anderson 1954). Usually the length of time required to collect a range of suspended-load data large enough to prepare a sediment rating curve prohibits the establishment of a supended-load station for the small watersheds in SCS programs. If such suspended-load records are available from nearby similar watersheds, however, the sediment yield rate can be derived and transposed in the same manner as reservoir sedimentation-survey data (pp. 6–5 and 6–6). The bedload portion of the sediment load is not measured in this method; it must be estimated. It can range from practically none to 50 percent or more of the total load.

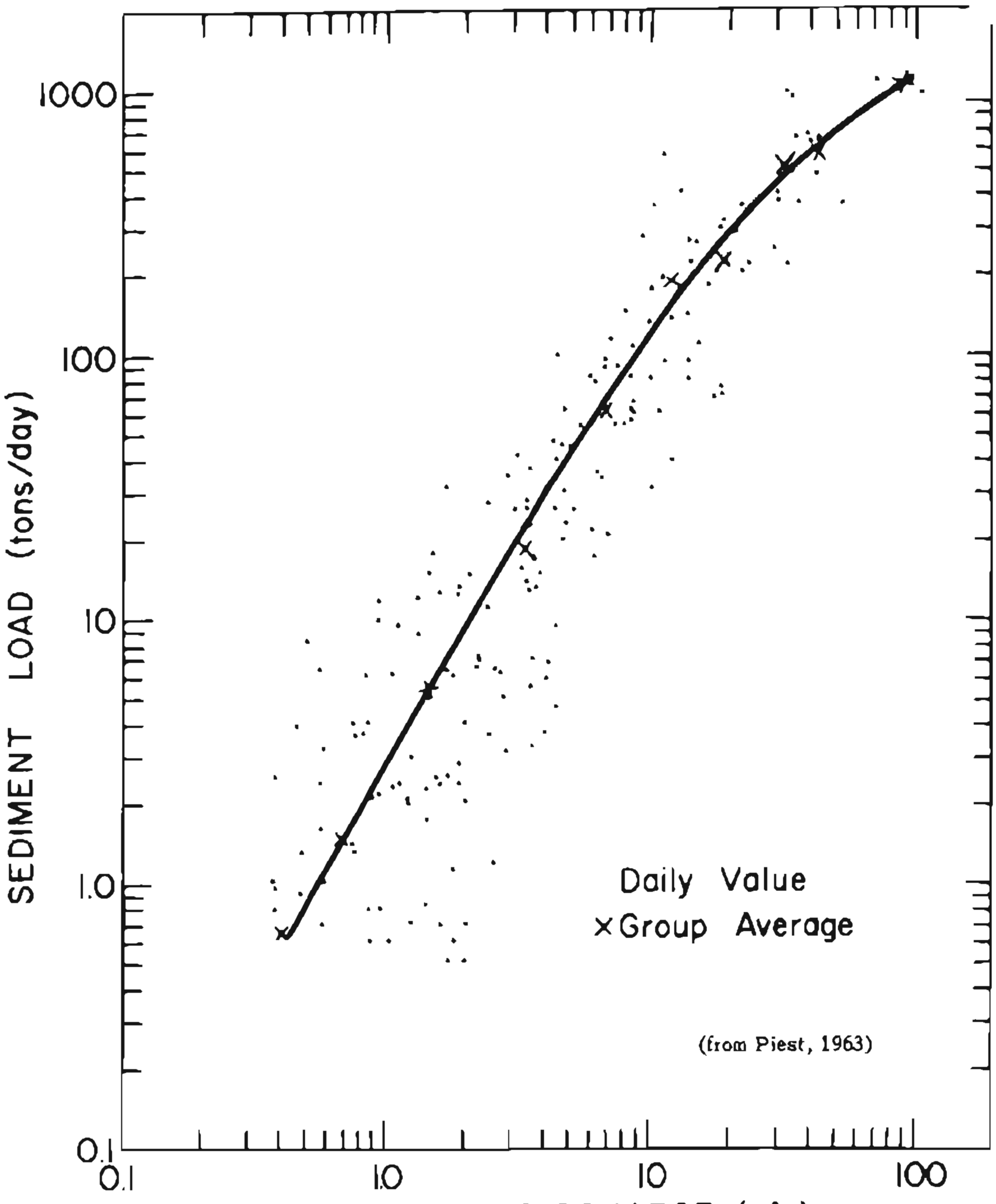
Predictive Equations

Predictive equations based on watershed characteristics have been developed in some areas to estimate sediment yield. These equations express sediment yield as a function of a combination of several measurable independent variables. The variables include size of the drainage area, annual runoff, watershed shape, relief-length ratio, average slope, an expression of the particle size of the surface soil, and others.

Such equations are not numerous but, where developed, they can be used with the understanding that they apply only to the specific area they represent (see Chap. 8).

Information Sources

Information on reservoir sedimentation surveys can be obtained from SCS reports and reports of other federal, state, and private agencies. Suspended-load data for a wide range of watershed sizes, geographic areas, and streamflow quantities are available from water-supply papers and special reports of the U. S. Geological Survey. Many project reports of the Bureau of Reclamation and U. S. Army Corps of Engineers contain sediment yield data for particular drainage basins. Reports of the Inter-Agency Committee on Water Resources should be consulted, as well as river basin reports such as those for the Missouri River and the Arkansas-White-Red Rivers. The Subcommittee on Sedimentation, Inter-Agency Advisory Committee on Water Data, periodically issues summaries of existing sedimentation surveys (Agricultural Research Service 1978) and inventories of sediment-load measurements in the United States (U. S. Geological Survey 1978). Copies of these are available through the committee's SCS representative. United Nations flood-control series bulletins



Direct runoff versus sediment discharge, by day, Pigeon Roost Creek Watershed 5, January 1957–December 1960

Figure 6-1.—A sediment rating curve.

contain some sediment-yield data. Sediment yield to bottom lands, fans, bays, deltas, and other features is evaluated in many of these reports. Sediment yield information is sometimes published in scientific and engineering journals (Gottschalk 1965, Holeman 1968, and Diseker and Richardson 1962), manuals (American Society of Civil Engineers 1975), or conference proceedings (Water Resources Council Sedimentation Committee 1976).

Determining the sediment delivery ratio is of primary importance to geologists if they are to make realistic estimates of sediment yield on the basis of computed gross erosion. No characteristic relationship is known to exist between sediment yield and erosion alone. Many factors influence the sediment delivery ratio and, because these are not uniform from watershed to watershed, the relationship between sediment yield and erosion varies considerably.

Influencing Factors

Each of the following factors can influence the sediment delivery ratio. There may be additional factors not yet identified.

Sediment Source

The sediment source affects the sediment delivery ratio. Sediment produced by channel-type erosion is immediately available to the transport system. Much of it remains in motion as suspended sediment or bedload. Materials derived from sheet erosion, however, often move only a short distance and may lodge in areas remote from the transport system. These materials may remain in the fields in which they originated or may be deposited as colluvium on more level slopes.

Proximity of Sediment Sources

Another factor that affects the sediment delivery ratio is the proximity of the source to streamflow. For example, although a large amount of material may be produced by severe erosion in an area remote from a stream, the delivery ratio and sediment yield may be less than those from a smaller amount of material produced by moderate erosion close to that stream.

Transport System

Runoff resulting from rainfall and snowmelt is the chief transport agent for eroded material. The ability to transport sediment depends on the velocity and volume of water discharge as well as on the amount and character of the material supplied to it. If the amount of sediment in transit exceeds the transport capacity of the system, sediment is deposited and the sediment delivery ratio is decreased. The frequency and duration of discharges affect the total volume of sediment delivered. The extent and condition of the transport system have considerable bearing on the amount of sediment the system can transport. A transport system with high channel density has the greatest chance of acquiring materials from the uplands and should have a high sediment-delivery ratio. The condition of the channels (clogged or open, meandering or straight) affects velocity and, consequently, transport capacity. A high-gradient stream, usually associated with steep slopes and high relief, transports eroded material efficiently. The converse is true of a low-gradient stream.

Texture of Eroded Material

The texture of the eroded material also affects the sediment delivery ratio. Transport of sand requires a relatively high velocity. Much of the sand is deposited in upstream areas wherever velocity drops significantly. Sand usually becomes part of the sediment load only if its source areas are adjacent to an efficient transport system. Eroded silt and clay are likely to stay in suspension as long as the water is moving, and most of such material is delivered downstream. Some of the coarser particles may be deposited as colluvium before they reach the transport system. The sands and larger grain-size materials are usually produced by channel erosion, and the silts and clays are common products of sheet erosion.

Depositional Area

Some sediment is deposited at the foot of upland slopes, along the edges of valleys, in valley flats, in and along main stream channels, and at the heads of and in reservoirs, lakes, and ponds. Such deposition within a watershed decreases the amount of sediment delivered to points downstream.

Watershed Characteristics

The topography of a watershed affects the sediment delivery ratio. Slope is a major factor affecting the rate of erosion. High relief often indicates both a high erosion rate and a high sediment-delivery ratio. The relief/length ratio (R/L ratio) often corresponds closely to the sediment delivery ratio. For use in the R/L ratio, relief (measured in feet) is defined as the difference between the average elevation of the watershed divide at the headwaters of the main-stem drainage and the elevation of the streambed at the point of sediment yield. Length is defined as the maximum valley length (in feet) parallel to the main-stem drainage from the point of sediment yield to the watershed divide. The shape of a watershed can affect the sediment delivery ratio. Channel density also affects the sediment delivery ratio; channel density and topography are closely related. The size of the drainage area is also important. Size can be considered a composite variable that incorporates and averages out the individual effects of variability in topography, geology, and climate.

Procedures for Estimating the Sediment Delivery Ratio

Determining the sediment delivery ratio requires knowledge of the sediment yield at a given point in a watershed and the total amount of erosion. If this information is available, determining the sediment delivery ratio is simple. Values for both these required items, however, usually are not available for most small watersheds.

Gross erosion in a watershed can be estimated by using standard SCS procedures (see Chap. 3). Sediment yield can be determinied from reservoir sedimentation surveys or sediment-load measurements.

Many reservoirs are not located at points where measurements of sediment yield are needed, and a program of sediment-load sampling may be long and expensive. But if the ratio of known sediment yield and erosion within a homogeneous area can be analyzed in conjunction with some measurable influencing factor, these data can be used to predict or estimate the sediment delivery ratio for similar areas where measurements are lacking.

In a given physiographic area, finding measurable factors that can be definitely related to the sediment delivery ratio is the goal of any delivery-ratio analysis. As already pointed out, many factors can affect the sediment delivery ratio. Some are more pronounced in their effect than others; some lend themselves to quantitative expression and others do not.

Statistical analysis is an effective means of developing information for estimating the sediment delivery ratio. The sediment delivery ratio is used as a dependent variable and the measurable watershed factors are used as the independent or controlling variables. For such an analysis, quantitative data on sediment yield, erosion, and measurable watershed factors must be available. Reservoir sedimentation surveys are a source of sediment yield data. Either maps or field surveys can be used to obtain the erosion information and determine the watershed factors. These data can be analyzed to develop a means for estimating the sediment delivery ratio for similar areas. Analyses of this type should be made in consultation with the geologist (sedimentation) of the appropriate national technical center (NTC).

Size of Drainage Area

Data obtained from past studies (Gottschalk and Brune 1950, Woodburn and Roehl[3], Maner and Barnes 1953, Glymph 1954, Maner 1957, Roehl 1962) are plotted in figure 6–2. The figure indicates a wide variation in the sediment delivery ratio for any given size of drainage area. The shaded area represents the range of data and the dashed line is the median. This analysis of data from widely scattered areas does show, however, that there is evidently some similarity in sediment delivery ratios throughout the country and that they vary inversely as the 0.2 power of the size of the drainage area. Rough estimates of the sediment delivery ratio can be made from figure 6–2, but any such estimate should be tempered with judgment, and other factors such as texture, relief, type of erosion, sediment transport system, and areas of deposition within the drainage area should be considered. For example, if the texture of the upland soils is mostly silt or clay, the sediment delivery ratio will be higher than if the texture is sand.

Somewhat more refined relationships between sediment delivery ratio and drainage area have been developed by regions at some NTC's and can be used in place of figure 6–2.

Relief-Length Ratio

The watershed relief-length ratio (Maner and Barnes 1953, Roehl 1962) is a significant indicator of the sediment delivery ratio. Empirical equations were derived to estimate the R/L ratio for the Red Hills of Texas, Oklahoma, and Kansas and for the southern Piedmont region of the Southeast. The significance of the R/L ratio may be less pronounced in some areas than in others, but it is related to, and seems to be a reasonable expression of, several watershed factors.

Source-Texture Analysis

In all the preceding discussion of methods of estimating the sediment delivery ratio, the delivery ratio is a percentage of total erosion. In many places the individual delivery ratio of the component parts of the total erosion is of concern to SCS geologists. Reasonable and realistic values for the delivery of component parts must be estimated from scanty data. One method of obtaining these estimates is to make certain determinations or assumptions about the source of various components of a known sediment yield.

In the following example the method of source-texture analysis is applied to a watershed in which the sediment sources are sheet erosion, gullies, roadbanks, ditches, and receding streambanks. The suspended-sediment yield (determined by sampling) consists of silt and clay, and the bedload (estimated as a percentage of the suspended-sediment yield) is sand. The streambed is in equilibrium and therefore is not considered a net source of sediment under existing conditions. Because of the texture of the sediment and the texture of the material available in the various sources, assume that all the sand is provided by gullies, roadbanks, and ditches and that the fine materials are provided by the receding streambanks and sheet erosion. Assume that 100 percent of the streambank material will be delivered to the point of measurement.

Use the following procedure to determine the sediment delivery ratio:

1. Compute the amount of sediment produced by each source or type of erosion in tons per year.
2. Determine the suspended-sediment yield of the watershed by sampling.
3. Establish a delivery ratio for the gullies and roadside erosion by comparing the amount of sand being carried past the point of measurement with the volume of material provided by gullies, roadbanks, and ditches.

Table 6–2 illustrates source-texture analysis for estimating sediment delivery ratios.

This procedure can be used to estimate the sediment delivery ratio in similar areas. Many broad assumptions are required in an analysis of this

[3] Woodburn, Russell, and J. W. Roehl. Unpublished study (1951). USDA, Agricultural Research Service, Oxford, Miss.

type, and the results will be only as good as the assumptions.

Source Deposition

Another method of determining the sediment delivery ratio is to make a field study of a watershed and estimate the amount of deposition that can be traced to any one source. The difference in the volume of such deposition and the volume of sediment produced by the source gives an estimate of the delivery ratio from that source.

Table 6–2.—Sediment source and the delivery ratio

Sediment source	Erosion[1]		Sediment yield[2]		Delivery ratio
	Sand	Fines	Sand	Fines	
	tons/yr	*tons/yr*	*tons/yr*	*tons/yr*	*Pct.*
Sheet erosion	—	900,000	—	[3]300,000	33
Channel erosion					
Gullies	350,000	—	280,000	—	[4]80
Road-banks	150,000	—	120,000	—	[4]80
Stream-banks	—	900,000	—	900,000	100
Total	500,000	1,800,000	[5]400,000	[6]1,200,000	70

[1]Determine by standard SCS procedures.
[2]Assume that all fines are from sheet erosion and streambanks and all sand is from gullies and roadbanks.
[3]Difference between total yield of fines and yield of fines from streambanks.
[4]Compute as ratio of total sand yield to total sand available; assume equal delivery ratio for gullies and roadbanks.
[5]Estimate bedload as a percentage of the suspended load.
[6]Determine from suspended-load measurements.

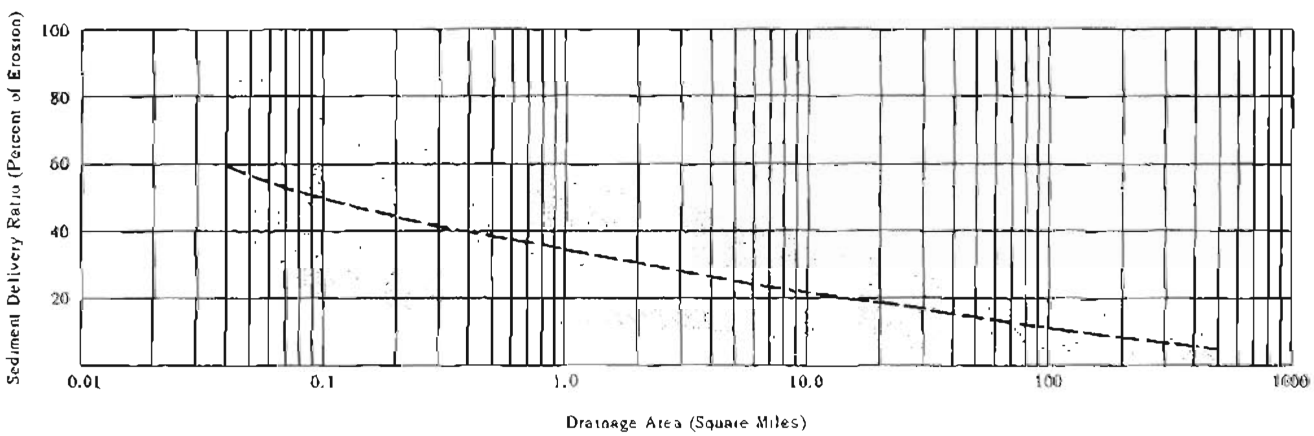


Figure 6–2.—Relationship between drainage area and sediment delivery ratio.

Summary

In many places data needed for detailed analyses are insufficient or nonexistent. Using an equation to obtain sediment data outside the physiographic area for which the equation was developed is generally not recommended. Yet SCS geologists must know the sediment delivery ratio to determine the sediment yield and the relative importance of various sediment sources and to recommend measures for reducing the sediment yield.

Information about the sediment yield from some watersheds is available in most areas of the Nation. These data can be obtained from suspended-load records and reservoir sedimentation-survey records. Comparing sediment yield with the calculated gross erosion indicates the expected sediment delivery ratio for an area. This kind of analysis is much broader than a detailed study, and extrapolating such an estimate to other areas can cause error.

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